The example of the Quartzite from the "Upper Quartzite Formation", “Trás-os-Montes e Alto Douro” (NE Portugal). Its characterization as natural stone for construction

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Abstract. The metaquartzites from Serra da Garraia and Zebras were studied. These rocks belong to the "Upper Quartzite Formation" of the “Parautochthonous Complex”. They are light grey and present, sometimes, a brownish patina. The quarries range from 2 – 10 m high and 25 – 40 m long. This study consists on the petrographic, chemical and physical-mechanical characterization of these rocks, aiming the determination of their potential as natural stone. The petrographic studies revealed that the rocks are mainly formed by quartz and white mica with accessory opaque minerals (titanomagnetite, magnetite, hematite) and zircon. The petrographic studies and SiO_2 and Al_2O_3 content revealed a different evolution for Garraia and Zebras quartzites, both in terms of textural maturity and mineralogical differentiation. The performed studies allowed the distinction between quartzites and quartzphyllites. The results of the physical-mechanical tests show that all the studied rocks can be used as natural stones for construction.

Introduction

The purpose of this work was to characterize the quartzitic rocks from Garraia Mountain and Zebras locality as ornamental stones and to give a contribution to increase the interest of population in the use of this resource.

Several valences were applied to study these stones, such as geological survey, mineralogy and petrography (optical microscopy, SEM, XRD and separation of heavy minerals), geochemistry and physical and mechanical tests (determination of water absorption at atmospheric pressure, determination of apparent density and open porosity, compressive strength, flexural strength under concentrated load, the abrasion resistance by means of the wide wheel Capon abrasion test and resistance to ageing by thermal shock).

Geology

The studied outcrops are located in “Trás-os-Montes e Alto Douro” (TMAD), NE of Portugal. The exploitations of Garraia (Ga1 and Ga2 samples) are located in Garraia Mountain, Palheiros parish, Murça municipality, Vila Real district. The exploitations of Zebras (Zb1 and Zb2 samples) also belong to the Vila Real district. They are located in Zebras locality, Vales parish, near the Santa Comba and Garraia Mountains, in the Valpaços municipality.

Trás-os-Montes and Alto Douro (TMAD) is located in the NW sector of the Iberian Massif (IM).

The studied sites are located in “Galiza Trás-os-Montes Zone” (GTMZ), in the “Parautochthonous Complex” (Fig. 1). They belong to the "Upper Quartzite Formation" (S_{PQ}) of Upper Silurian age [1,2,3].

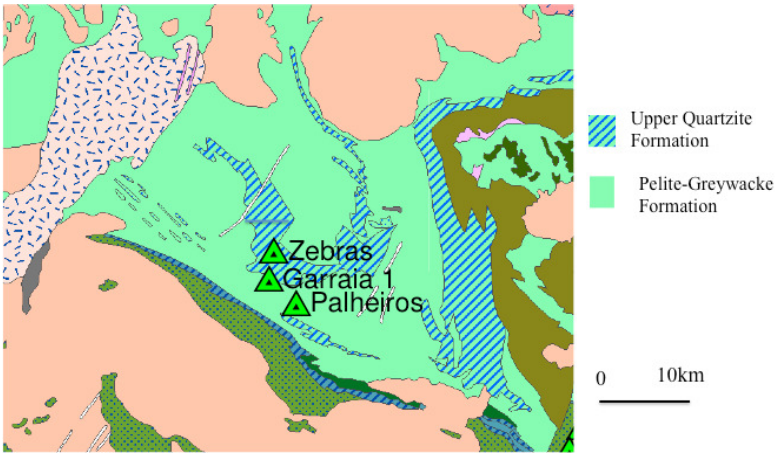

Fig. 1- Location of the studied sites (From [2], adapted].

Characterization of the Quarries

Garraia 1 is a quarry 5 m high and 40 m long. The quartzite is laminated, with a greyish colour with a brownish patina. The rock exhibits a sub-horizontal slate cleavage N90ºE to N110°E (Fig. 2). There are several joint systems (Fig. 3).

Fig.2- Quartzite on Garraia 1 quarry

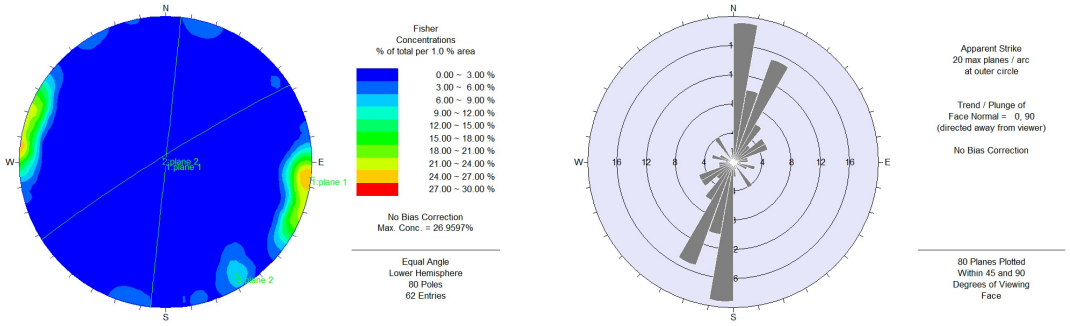

Fig. 3- Joints diagram from Garraia 1.

Garraia 2 quarry is smaller than Garraia 1. The stone is a less laminated quartzite with whitish colour but sometimes exhibiting a brownish patina. Stratification is parallel to slate cleavage (N75°E,

18°N and N55°E, 15°N). Some quartz veinlets N120°E, 90° existe in the quarry (Fig.4). The joint systems are represented in Fig. 5.

Fig. 4- Aspect of quartzite with quartz veinlets from Garraia 2.

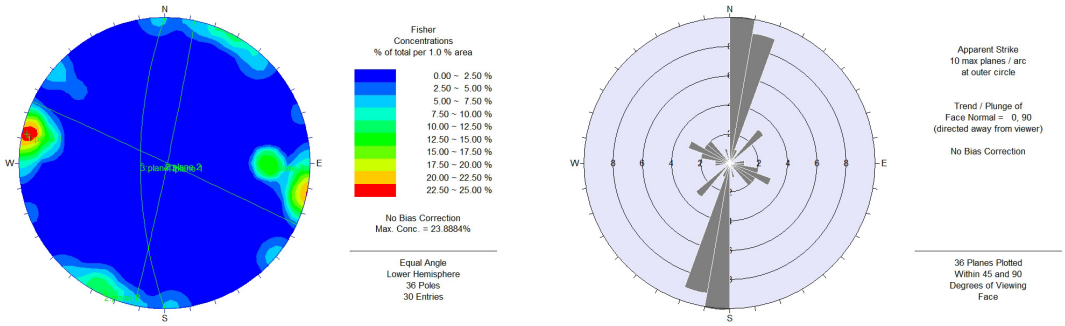

Fig. 5- Joints diagram from Garraia 2.

Zebras 1 quarry is 25 m long and 4 m high on slaty quartzite. The rock shows a brownish patina, is well laminated and sometimes exhibiting quartz nodules. Stratification is parallel to the slate cleavage (N60°E,05°N). The different joint systems are represented in Fig. 6.

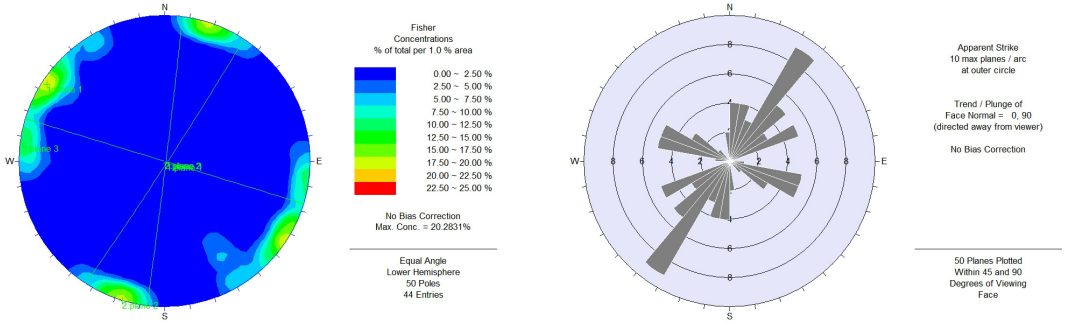

Fig. 6- Joints diagram from Zebras 1.

Zebras 2 is a recent exploitation, 2 m high on slate quartzite. The slate cleavage N30°E, 12°E is parallel to stratification. It is well visible an horizontal crenulation N100°E is well visible. Spaced quartz veinlets N140°, 90° are also observed. The main joint system is sub-vertical and with orientation N10°E to N30ºE; N60°E and N100°E.

Petrography

The samples referred as Ga1 and Ga2 are characterized by having a light gray color. They are finely laminated and show an evident slate cleavage. Although with fine grain size sometimes small quartz clasts and some oxides are visible (Ga1). Quartz is the most abundant mineral in these rocks, but their composition also includes fine white mica (less important in Ga2), corresponding to a matrix, opaque minerals, zircon and oxides. The texture is granoblastic to lepidoblastic (Fig. 7).

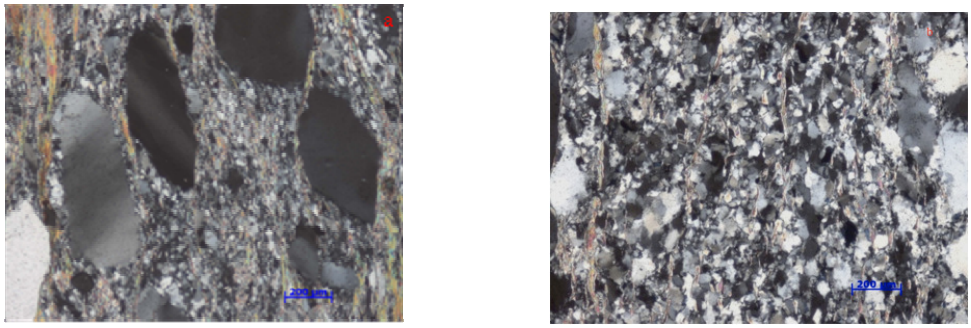

Fig. 7- a: Lepidoblastic texture with quartz clasts and mica and recrystallized quartz in Ga1, NX; b: lepidoblastic texture in Ga2, NX.

Zb1 is a grey rock, usually exhibiting a brownish patina (Fig. 8a). This rock has lepidoblastic texture and a foliation marked by alignments of white mica and stretched quartz crystals (Fig. 9a). On its composition, this rock has also opaque minerals, oxides and zircon. Zb2 is a light grey rock. Both samples are fine grained and the minerals, with the exception of quartz, cannot be macroscopically identified (Fig. 8b). These rocks have lepidoblastic texture marked by deformed quartz and white mica (Fig. 9b). Zircon is an usual acessory mineral, showing a rounded shape.

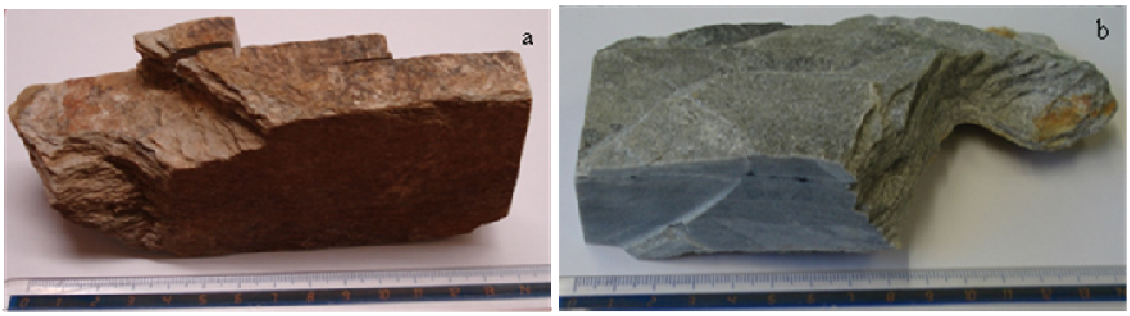

Fig. 8- a: Zb1hand sample aspect with brownish colour; b: Zb2 hand sample aspect.

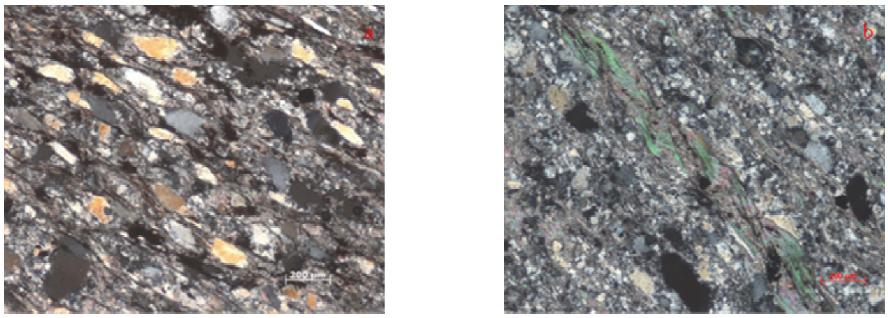

Fig. 9- a: Lepidoblastic texture, quartz stretched parallel the foliation in Zb1, NX; b: lepidoblastic texture with crenulation in Zb2, NX.

Opaque minerals are frequent, occurring under reduced size and subhedral to anhedral shapes.

The observation of heavy diamagnetic mineral concentrates reveals zircon mixed grains (quartz with opaque minerals). Zircon is present in all studied samples however, in Ga1 has the peculiarity of being pink, while in the other samples it is clear or translucent yellow. The paramagnetic fractions showed that an abundant mineral in all samples, exhibiting a rounded shape. The study of this mineral by SEM revealed that it is a titanomagnetite sometimes with addition of Cr and Ni. Hematite under the form of subhedral crystals is another mineral also present in all samples. Magnetite is present in all samples.

Geochemistry

In Table 1 presented the results of whole rock analyzis for major elements of Garraia (Ga 1 and Ga2) and Zebras (Zb1 and Zb2) stones and for comparative study two samples from Cubo Unit (Cb) also described as quartzite (MA 132) and as a quartzphyllite (MA 133) belonging to the "Upper Quartzite Formation" occurring to the NW of studied quarries at Vila Pouca de Aguiar area [4]. It appears that Ga1, Ga2 and Zb2 rocks are enriched in SiO_2 with more than 90% (91.2%, 96.0%, 90.3%, respectively) while Zb1 has 79.13%. Zb1 is the richest in Al_2O_3 (11.44%) and Ga2 the poorest (2.3%). For the remaining major elements, we must refer the low values of Na_2O, CaO, P_2O_5 and MnO (<0.1%). The values of K_2O range between 0.77 and 3.38%, the latest one occurring at Zb1 which is also the richest in Al_2O_3. The comparison results with "Cubo Unit" (Cb) suggests that Ga1, Ga2 and Zb2 correspond to (meta) quartzites such as Ma 132 and Zb1 corresponds to a quartzphyllite, such as MA 133, with the corresponding greater abundance of white mica

Table 1 – Whole rock chemical analyzes for major elements.

		Ga1 (1)	Ga2 (2)	Zb1 (3)	Zb2 (4)	MA 132 (5)	MA 133 (6)
SiO_2	%	91.2	96.02	79.13	90.3	92.50	78.99
Al_2O_3	%	4.62	2.3	11.44	4.86	4.69	10.48
Fe_2O_3 (T)	%	1	0.63	2.82	0.96	0.32	3.08
MnO	%	0.002	0.002	0.007	0.003	0.00	0.03
MgO	%	0.14	0.07	0.36	0.13	0.00	0.65
CaO	%	0.03	0.01	0.02	0.01	0.00	0.08
Na_2O	%	0.03	0.02	0.09	0.04	0.02	0.85
K_2O	%	1.6	0.77	3.38	1.62	1.16	2.83
TiO_2	%	0.207	0.1	0.506	0.193	0.16	0.48
P_2O_5	%	<0.01	<0.01	0.05	0.02	0.00	0.11
LOI	%	0.81	0.34	2.26	0.92	1.02	2.17
Total	%	99.65	100.3	100.1	99.05	99.87	99.75

(1) Quartzite, (2) Quartzite, (3) Quartzphyllite, (4) Quartzite, (5) Quartzite [4], (6) Quartzphyllite [4].

The Fig. 10 presents the SiO_2–Al_2O_3 diagram. The diagram reveal that all samples are mineralogically mature, because all of them have SiO_2 content over 79%. However a different evolution for Garraia and Zebras in terms of textural maturity and mineralogical differentiation is evident. Ga2 sample is the most mature and the most evolved and Zb1 sample the less mature and evolved. Ga1 e Zb2 remain between Ga2 e Zb1, but on mineralogical differentiation and textural maturity closer to Ga2. The Fig. 11 shows the enrichment on Al_2O_3 and TiO_2 from Ga2 to Zb1 related to the amount of matrix, which is poor in Ga2 and more abundant in Zb1, probably with ilmenite being associated with micaceous matrix.

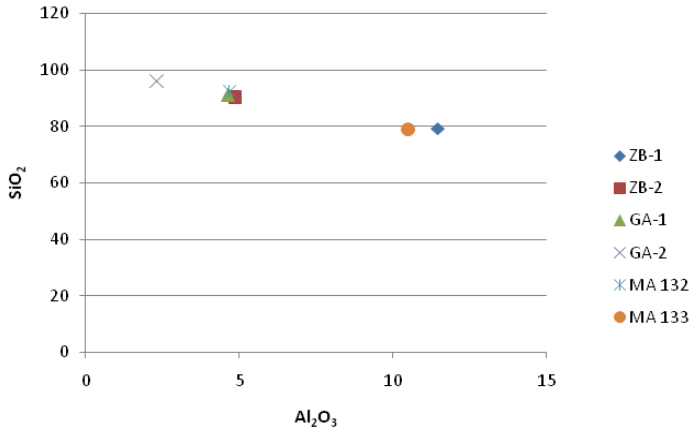

Fig. 10- SiO_2 - Al_2O_2 aplot diagram.

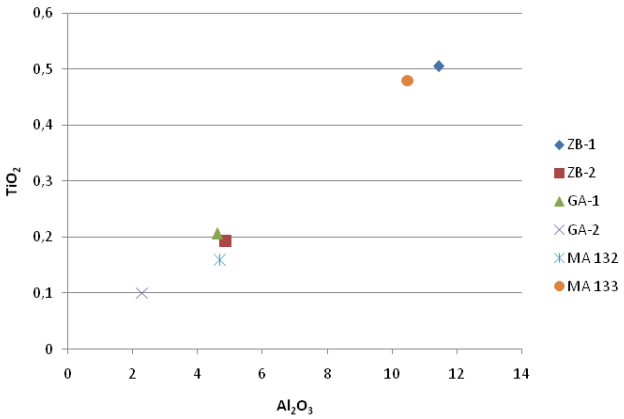

Fig. 11- TiO_2 - Al_2O_3 aplot diagram.

Physical and Mechanical Characterization

The rocks studied were subjected to laboratorial tests as essential to their physical and mechanical characterization and definition of their use [5]. Ga1 sample is set to 1059 RO, Zb1 as 0986 RO and Zb2 as 1070 RO. In table 2 we can see the results of each test for each rock are shown. Fig. 12 shows the Zebras sample aspect after compressive strength test and the Zb1 and Zb2 specimens aspect after flexural strength under concentrated load test. At the end of the 20 cycles of thermal shock, the specimens show almost the same aspect they had before the test.

Table 2 – Physical and mechanical tests.

	Ga 1	Zb 1	Zb 2
Water absorption at atmospheric pressure (%)	0.7	0.3	0.3
Apparent density (kg/m^3)	2630	2630	2650
Open porosity (%)	1.6	0.8	0.8
Compressive strength (MPa)	150	89	87
Flexural strength under concentrated load (MPa)	35.6	29.6	37.7
Abrasion resistance – Wide wheel Capon abrasion test (mm)	19	18.5	16.5
Resistance to ageing by thermal shock (loss of mass %)	0.07	0.01	0.03

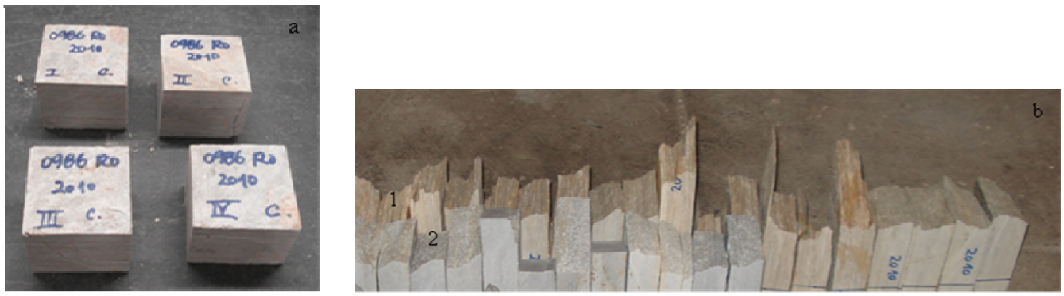

Fig. 12- a: Zb1 specimen aspect after compressive strength test; b: Zb1 (1) and Zb2 (2) specimens aspect after flexural strength under concentrated load test.

Concluding Remarks

The studied samples are laminated stones, with fine granularity and different degrees of oxidation. The Ga2 and Zb2 samples are fine grain and the minerals cannot be macroscopically identified, in Ga1 and Zb1 it is possible to identify small quartz clasts.

Using petrographic methods, it is possible to identify a specific orientation of quartz and white micas, which confers to all the stones a dominant lepidoblastic texture. In their mineralogical composition, all the samples present opaque minerals, identified by SEM (titanomagnetite which is the most abundant and hematite). Ga2 presents less mica and more quartz content, which indicates a lack of matrix. Zb1 is the richest in mica. This fact confirms the results obtained by chemical analysis and Ga2 is the sample with highest SiO_2 content (96.02%) and lowest Al_2O_3 content (2.3%). On the contrary, Zb1 presents lowest SiO_2 content (79.13%) and highest Al_2O_3 content (11.44%).

SiO_2 and Al_2O_3 values and the petrographic studies revealed a different evolution for Garraia and Zebras samples in terms of textural maturity and mineralogical differentiation. Ga2 sample is the most mature and the most evolved and Zb1 sample is the less mature and the less evolved. The studies allowed the distinction between quartzites and quartzphyllites: Ga1, Ga2 and Zb2 are quartzites and Zb1 a quartzphyllite.

The results of the physical and mechanical tests allowed to consider the following uses for the studied stones (Table 3).

Table 3 – Possible uses for the studied stones.

	Ga1	Zb1	Zb2
Rustic masonry	+	+	+
Bearing masonry / columns	+	+	+
Lintels	mainly indoors		+
Pavements of high traffic	conditioned use outdoors	+	
Pavements of very high traffic			+
Cladding	mainly indoors	+	+
Roofing (as slabs of different thicknesses, not as discontinuous roofing)		+	+

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